Update a Pest Management Evaluation For the Almond Industry

Contract Number: 99-0198

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March 9, 2000

Prepared for the California Department of Pesticide Regulation

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This report was submitted in fulfillment of DPR Contract Number: 99-0198 for the "Update A Pest Management Evaluation for the Almond Industry " under the sponsorship of the California Department of Pesticide Regulation. Work was completed on March 9, 1999.

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Abstract

California is the only state in the United States to commercially produce almonds. Over the last five years, California has produced, on average, 67% of the world's almonds. The state's 6,000 almond growers farm about 573,000 acres in the 1998-1999 growing season. Out of these 573,000 acres, 460,000 are bearing trees and 113,000 are non-bearing. There were 28,727 new planting of almond trees during this time. In 1998, almonds were California's top agricultural export with a value of $780 million . California sells almonds to nearly 100 various nations worldwide, reaching a total of nearly $1 billion. The almond industry, located primarily in the San Joaquin and Sacramento Valleys, faces a wide variety of pests and diseases across a broad geographical area. Approximately 30 varieties of almonds are grown commercially, with Nonpareil accounting for 40-45% of the production. In 1998, there were 208,000 acres of the Nonpareil cultivar. Carmel (88,500 acres), Butte (44,000 acres), and Mission (28,000 acres) round out the major cultivars in California.

A variety of insect and mite pests attack almonds in California. These pests are present in all almond-growing areas of the state and occur at damaging levels most seasons. The most significant pests include navel orangeworm (NOW), peach twig borer (PTB), San Jose scale, ants, and mites. There are a variety of chemical control practices, cultural control practices, biological control practices, and alternatives that can be employed to control these pests.

Weeds can cause a multitude of problems in almond orchards by reducing the growth of young trees because they compete for water, nutrients and space. Weeds can also increase water use, cause vertebrate and invertebrate and other pest problems. There are a variety of chemical control practices, cultural control practices, biological control practices, and alternatives that can be employed against weeds.

Almonds are subject to numerous diseases that reduce yield and quality of the crop and sometimes weaken and kill trees. These diseases include brown rot, anthracnose, and shot hole. For many of the more serious diseases, the only management tools available are preventative treatments that protect flowers, leaves, and fruit prior to infection.

Passage of the Food Quality Protection Act (FQPA) has raised the possibility that almond growers may lose some of the traditional chemical tools they have used to combat these pests and diseases. Additionally, concern is being raised over runoff and infiltration of pesticide residues into local watersheds. Research is underway into various alternative methods for controlling the pests and diseases that affect almond production. Those various practices and strategies for reducing pesticide risks on the farm are discussed in this evaluation.

ALMOND PEST MANAGEMENT EVALUATION

A. PRODUCTION

⁕ In North America, California is the only state that commercially produces almonds. California is ranked first in almond production nationwide and produces 99.9% of the United States almonds (29). As of 1998-1999 growing season, California almonds grew on 573,000 acres. Approximately 20% of those acres are non-bearing ((30).)

⁕ The California almond industry has approximately 6,000 growers farming about 573,000 acres during the 1998-1999 growing season. Between 1992 and 1998 California averaged 566,266,000 pounds of almonds (29).

⁕ Average annual crop value during 1992-1998 increased to $935,546,000 (29).

⁕ California exports approximately 74% of the annual almond crop (29). Leading nations importing California grown almonds in 1998-1999 are: Germany 22%, Japan 9%, Spain 13%, India 6%, and France 6% (29). Almond sales to the Middle East, China, the Baltic States, and Eastern European nations were strong during the 1998-1999 season (29).

⁕ The value of one bearing acre in 1997-1998 is $2,755.00.

B. PRODUCTION REGIONS

Over 99% of the almonds in California are produced in the San Joaquin and Sacramento Valleys. Approximately 80% of the production is in the San Joaquin Valley. Kern and Fresno Counties in the south and Merced and Stanislaus in the north are the highest producing counties in the San Joaquin Valley (15). Glenn, Butte, and Colusa Counties in the Northern Sacramento Valley account for approximately 15% of the annual production in the state with the remainder being grown in the southern part of the Sacramento Valley (15).Despite being grown throughout the Central Valley, the top five producing counties in California are: 1) Stanislaus County 20%, 2) Kern County 17%, 3)Merced County 16%, 4) Fresno County 12%, and 5) Madera County 9% (29). Other top producing counties are San Joaquin County, Butte County, and Colusa County.

C. CULTURAL PRACTICES

Approximately 30 varieties of almonds are grown commercially in the state with Nonpareil accounting for about 40-45% of the production. Other important varieties grown in California include Carmel, Mission, Price, Butte, Neplus, Fritz, and Monterey (14). The vast majority of major commercial cultivars of almond in California must be cross-pollinated by insects, primarily honeybees (6). Honeybees in over-wintered colonies are the only pollinators currently available in adequate numbers to service the almond industry in California. Planting patterns vary, but generally in newer plantings, the main variety is planted in alternate rows with a compatible pollinizer that overlaps the main variety at bloom-time(6).

Selected varieties are grafted onto rootstocks. Rootstock selection is based on cultivar compatibility, soil texture and drainage, pests (primarily nematodes) and weather conditions of the orchard site. Although several rootstocks are available, the two main rootstocks used are Nemaguard and Lovell peach (6). Other less common rootstocks include Nemared, Marianna 2624 plum, various peach and almond hybrids and almond itself (6). Both varieties and rootstocks vary in susceptibility to diseases, nematodes and insect pests.

Almonds are most productive on loam-textured, deep uniform soils. However, many orchards are planted in less than ideal sites but produce economical crops with soil modification and proper care. Irrigation is essential for the economic production of almonds in all parts of the state. Flood, furrow, and sprinkler irrigation are predominant with drip and micro-sprinkler irrigation being used more often, especially in marginal soils (6).

Non-cultivation of orchard soils with herbicide-treated strips down tree rows is common. Orchard floor management is of particular importance to an almond grower because the crop is picked up off the soil surface after being knocked from the trees and swept into windrows. Whether an orchard is tilled, non-tilled, herbicide-treated, or cover-cropped, a primary consideration when performing any cultural operation during the year must be to ensure that the orchard floor is the best possible condition for harvesting (6).

Almonds begin blooming in mid-February before the danger of frost has passed. Bare and moist ground absorbs more heat and can reduce the threat of frost damage. Early season frost protection by close mowing or herbicide treatment is also an important consideration in orchard floor management (5).

D. INSECT/MITE CONTROL

California is a dominant player in the production of almonds. This high value crop adds over one billion dollars to the state's economy, but these high crop yields are dependent on the use of agricultural chemicals to prevent crop losses by insect and mite pests. Combating these pests and maintaining a high quality crop is one of the almond growers' biggest challenges. The regulatory threat of FQPA may eliminate some of the most effective chemical pest control tools used in almonds. This combined with the growing concern statewide of pesticide residues entering local streams and rivers, the increasing possibility of pesticide resistance, and the EPA's concern over farm workers' exposure to pesticides are fueling the effort to find reduced risk alternatives. These concerns are now driving the work of University of California researchers, University of California Cooperative Extension staff, the Almond Board of California, the Community Alliance with Family Farmers, Pest Control Advisors (PCAs) and California farmers to join together in the Almond Pest Management Alliance (PMA) to develop and implement good alternatives to these targeted agricultural chemicals.

A number of California farmers have joined with their peers to form associations whose purpose is to develop and implement sustainable farming methods. By adopting sustainable farming practices, farmers use production techniques that are both environmentally friendly and economically viable. These methods are not just about reducing pesticide use, but involve the system as a whole, using pest resistant plant varieties, building up soil organic matter, promoting beneficial insects, more efficient use of irrigation water, and less reliance on chemical fertilizers. Some of these methods are associated with creating conditions that may result in lower pesticide use. (29)

One program which promotes the adoption of sustainable farming practices is the Biologically Integrated Orchard Systems (BIOS) project, an attempt to reduce grower dependency on broad-spectrum pesticides with a whole systems approach. The BIOS approach is a mixture of methods developed by farmers, UC researchers and farm advisors, the UC IPM project, local PCAs, and BIOS staff. A subset of reduced risk pest management strategies has emerged from the BIOS program that may be successful for almond production, even if the entire BIOS system is not implemented. This subset of pest management practices in almonds involves the complete elimination of broad-spectrum insecticides for NOW and PTB, which significantly reduces mite problems and may help control SJS as well.

In the BIOS approach, PTB is controlled with springtime Bt sprays, NOW is controlled with winter sanitation and an early harvest, while mites and SJS are not a significant problem is most cases. If they are, mites and SJS can be controlled with a dormant spray of horticultural oil alone. In the areas where BIOS operates- - Madera, San Joaquin, Merced, Stanislaus, and Colusa counties - - it appears almonds can be grown economically without the use of broad spectrum insecticides. It is unknown if the BIOS approach can be successful in other counties located in the southern San Joaquin Valley. However, it is hoped that some of these successful orchard management practices can be utilized by all California almond growers. These practices are based on UC IPM research and the hope is that outreach efforts and demonstration orchards will provide growers with the information they need to implement reduced risk practices.

There are a variety of insect and mite pests that attack almonds in California. These pests are present in all almond-growing areas of the state and occur at damaging levels most seasons. A brief description of the major insect and mite pests follows. Also included are the current chemical alternatives as well as the cultural and biological options currently available.

Navel Orangeworm, *Amyelois transitella*

Navel orangeworm (NOW) is the most important insect pest in almonds (2). NOW attacks most soft-shell cultivars, or nuts with poor seal, feeding inside the nuts on the kernels. Some hard shell and some poor sealed nut cultivars are more or less resistant to attack by NOW. It not only destroys kernels but also is associated with fungi responsible for aflatoxins. (2). Navel orangeworm larvae cannot enter sound nuts before hullsplit so damage occurs after hullsplit and before harvest. Navel orangeworm overwinters as larvae inside mummy nuts left on the tree and in trash nuts left on the ground and in tree crotches. Moths of the overwintered brood emerge in spring and lay eggs on mummy nuts or nuts damaged by peach twig borer, which act as a food bridge for this generation. After hatching, white neonate larvae of the first generation again enter nuts damaged by peach twig borer (2). This makes peach twig borer control extremely important. Larvae

mature inside nuts producing large amounts of frass and webbing. Mature larvae are white or pinkish and may reach 5/8 inches in length. After hullsplit, adults lay eggs directly on the hull of sound nuts and the tiny larvae enter nuts through the shell seal and do not emerge until they are adults (5). There are 3 to 4 generations per year. Thirty-percent damage is not uncommon in late harvested orchards (16). **Monitoring:** NOW egg traps are used to monitor NOW and provide proper timing for applying in-season insecticide applications. NOW egg traps should be placed in the almond tree, 4-6 feet above the ground, on the north side, and away from a sprinkler in late April or early May. These traps should be baited with NOW bait which contains almond oil. Once the first egg is detected, the day-degree calculations should begin. UCCE farm advisor Joe Connell has developed the day-degree calculations which can be calculated using the UC IPM web page: www.ipm.ucdavis.edu. The cut-off temperatures are 55° F and 94° F. Other important information to choose is the double triangle and vertical cut-off options. Follow the directions as to appropriate county, dates, and weather station. When the first egg is noticed on the egg trap, the first biofix, the first generation of NOW has begun, this is day-degree zero. The second generation will begin at 1025 day-degrees from the first biofix. From this second generation biofix, 1025 day-degrees, the third generation will begin in 692 day-degrees, or approximately 1725 day-degree from the first biofix. If necessary, the fourth generation will be at 2050 day-degree from the first biofix. From the first biofix, subsequent generations can be predicted using this model. Referencing historical data, subsequent generations can be plotted for the season.
No single control tactic, used alone, will control NOW. In order to manage NOW effectively, orchard sanitation, removing mummy almonds from trees either by another shaking or poling them down, early harvest, on-farm fumigation, and chemical control are practiced.

1. Chemical Control

Pre-harvest chemicals can be an important component of a NOW control program and can provide up to 50% control (2). However, non-chemical control can achieve up to 90% control (2). "The most effective way to prevent economically destructive populations of navel orangeworm is to remove mummy nuts from the trees by February and destroy them. When a good orchard sanitation program is carried out in an orchard located at least 1/4 mile from infested trees, together with an early harvest, usually no sprays are needed for navel orangeworm damage" (2).

Fumigation
On-farm fumigation to kill eggs and neonate larvae before nuts can become infested is an important part of the navel orangeworm control package.

Aluminum Phosphide - Labeled at the rate of 100–200 pellets or 20-40 tablets per 1000 cubic feet. Applied to harvested nuts from 11.6% of the acres at an average rate of 0.02 lb. a.i. (1) Applied under tarps prior to hulling and processing.

Azinphos-methyl - 28 days PHI. Applied mid-season to 18.8% of the acres by ground at an average rate of 2-lb. a.i. per acre (1). Azinphos-methyl is the most effective material against navel orangeworm when applied post-bloom. It is somewhat selective for predaceous mites but highly toxic to parasitic wasps and generalist predators (5). This is the preferred material because of its longer residual. It is less disruptive to natural enemies and has some fuming action.

Esfenvalerate – (see peach twig borer). Will reduce navel orangeworm if used during growing season. Will cause mite outbreaks.

Permethrin – (see peach twig borer). Effective against navel orangeworm if used during growing season. Usefulness of this material is limited due to severe mite flare-ups following its use during the growing season (5).

Carbaryl - 0 days PHI. Applied mid-season to 1% of the acreage by ground at an average rate of 3.2-lb. a.i. per acre (1). A useful material because it can be applied in an emergency situation up to 1 day prior to harvest. Effective on navel orangeworm, peach twig borer and other lepidopterous pests. It will also control San Jose scale crawlers and eriophyid mites. Extremely disruptive to natural enemies and will generally cause mite outbreaks. It is toxic to honeybees (5).

Phosmet - (see peach twig borer). Will also reduce navel orangeworm. Used commonly as hull-split spray for last NOW generation. Fits well within an IPM program.

Chlorpyrifos – Most use is for ants and peach twig borer. Can control NOW and is a viable alternative to azinphos-methyl.

Methidathion – Not used for NOW.

Diazinon – Is not registered for in-season use in California, therefore not used to control NOW.

Malathion – Is not effective against NOW.

2. Alternatives

It is possible to implement an effective NOW control program without relying on pesticides (2). The use of cultural control practices (see below) are considered to be the most effective method of NOW control. Pesticides are usually not needed for this pest, unless an untreated source of NOW infestation is located nearby (less than 1/4 mile).

3. Cultural Control Practices

Many growers have been successful using winter sanitation and an early harvest for control of NOW. Winter sanitation, reducing mummies to two or less per tree by the end of February and destroying all mummies left on the ground, will help reduce overwintering populations of NOW. Also important is good sanitation around hullers, bins, dryers, and buildings where nuts are stored or handled. (2)

Equally important for NOW control is an early and timely harvest (especially the soft shelled varieties). Getting nuts off the trees, picked up, hulled and to the handler for fumigation as early and as quickly as possible will be most effective at controlling NOW. The earlier soft-shell varieties are harvested, the less time they will be exposed to NOW larvae and the lower the infestation will be. (2)

4. Biological Controls

In California, there are 21 documented insect enemies of the NOW egg and larvae. It is possible to increase the beneficial insects in the orchard in selected almond producing counties by releasing additional beneficial insects to augment the population. Adult *Goniozus legneri* wasps can be released to help with the biological control of NOW. Results from these releases are variable, but have been shown in some cases to help achieve good NOW control, although not to a greater degree than with good sanitation methods.

It is essential to provide flowering plants to feed adult beneficial insects. The offspring of many beneficial insects feed on NOW larvae, but the adult beneficial insects actually feed on nectar (and pollen) from flowers. A flowering cover crop or an insectary hedgerow can be a good food source for adult beneficial insects. UCCE Farm Advisor, Rachael Long in a study using almond orchards, showed that beneficial insects will feed on cover crop nectar and fly up to 6 feet into the tree canopy and lateral distances up to 100 feet, pointing out that a flowering cover crop will feed adult beneficial insects deep in the orchard block (20).

Another method for controlling NOW is currently being tested in field trials. The idea is to spray almond oil (or an analog made from soybean oil) on the trees. The female NOW perceives all elements of the tree as an almond nut and will lay eggs on branches and leaves, mostly avoiding the nuts. Larry Phelan at Ohio State University invented this method by using a formulation of almond oil fatty acids, the anti-transpirant Vapor-Guard, and some antioxidants to extend the lifetime of the fatty acids. Spraying every other row gave 90% control. (20)

Multiple sprays of *Bacillus thuringiensis* (Bt) at hull split can also control NOW. Some growers have also had success controlling NOW by using Bt sprays combined with releases of *Goniozus* (27).

UC researchers are working on a system to use sex attractant chemicals (pheromones) to confuse male NOW. The pheromone is periodically released by a "puffer". The male NOW becomes confused and cannot find the females, thus no mating occurs. This system has not been refined, and is not commercially available at this time. It should be noted there are concerns over the cost of producing this pheromone.

5. Other Issues

NOW can be a very damaging pest, but there are options for controlling this pest and minimizing economic damage. It has been documented that this pest can be effectively controlled without sprays when the right cultural practices are implemented. The reduced risk strategies include: the cultural practices of winter sanitation and early harvest, beneficial insect releases, and providing habitat for beneficial insects, possible use of pheromone mating disruption, or egg laying disruption. Controlling NOW takes time and involves multiple operations but cultural controls have been proven effective.

Peach Twig Borer, *Anarsia lineatella*

Peach twig borer (PTB) is a major pest in almonds and other stone fruits. PTB damages almonds by feeding in rapidly growing shoots making it difficult to train young trees. However direct feeding on nutmeats render them to be discarded creating the greatest economic damage. PTB damaged nuts also contribute to navel orangeworm problems. Prior to the movement of navel orangeworm into California, the PTB was the most important worm pest of almond (6). In the absence of adequate control measures, the potential for extensive loss to PTB still exists.

Adult PTB are 8-11 mm long with steel gray mottled forewings. Eggs are yellow-white to orange and bluntly oval with surface reticulations. They are laid on fruit surfaces, on twig terminals, or on the undersides of leaves. Larvae are brown with distinctive alternating dark and light bands around the abdomen. In almonds the brown pupae may be found between the hull and shell of dried nuts and other places on the trees (5).

PTB overwinters as first or second instar larvae in cells, primarily under the thin bark in limb crotches on first-to-third year wood. Overwintered larvae begin emerging at about bud break and feed on young leaves and buds. As terminals elongate, maturing larvae establish themselves in a single shoot or terminal and mine the interior of the shoot causing wilting and death of the shoot. Overwintered generation adults usually begin emerging in April. Moths of this generation generally oviposit on shoots but can infest developing fruit causing serious nut loss when populations are heavy. Adults from this generation emerge in late June or early July with most attacking fruit directly. Larvae feed in hulls or directly on the meats, often causing serious crop loss. Peach twig borer larvae begin entering overwintering sites in August and continue throughout the fall. There are 4 or more generations each year (2).

Soft-shell almonds are most susceptible to damage from PTB. Before insecticides were available, the California Almond Growers Exchange recorded damage as high as 71% (6). In soft-shell varieties, it is not uncommon to experience >30% nut damage in untreated orchards. **Monitoring:** Monitoring for PTB begins during the dormant period. By inspecting 100 dormant spurs in December-January and counting the number of dormant spurs with PTB hibernacula present may provide information regarding populations in the orchard. If there are more than 10 (10%) dormant spurs with hibernacula present, then a dormant spray may be necessary. If there is no hibernacula present or less than 10% on dormant spurs, then a dormant spray may not be necessary, thereby reducing the amount of sprays. If there is a question as if there is a pertaining to spraying, re-sample in a few days and re-evaluate. Pheromone traps are widely used to monitor PTB phenology and time in-season treatments. Pheromone traps should be placed on the north side of the tree, 4-6 feet above the ground, and away from the sprinklers in the middle of March. The pheromone septa should be changed every two weeks and the bottom of the traps should be changed when necessary or when moth captures total 200. Changing the bottom of the trap may occur every week if there is a large population. By using the PTB model which can be found at www.ipm.ucdavis.edu, the populations can be monitored season long. At biofix, the second generation should begin at 1065 day degrees, the third generation at 2115 day degrees, and the fourth at 3165 day degrees. The most effective timing is 400 to 500 degree-days after the beginning of each flight (5). Other forms of monitoring for PTB populations require more study such as shoot strike counts and using corrugated cardboard around the trunks of the trees to determine larva levels.

1. Chemical Controls

Traditionally, PTB was controlled with a dormant or delayed dormant application of one of the materials listed below.

Diazinon – Not labeled for in-season use. Applied to 18.5% of the acres, pre-bloom, at the average rate of 2-lb. a.i. per acre (1). It is extensively used for ground applications mixed with petroleum oil during dormant period for control of PTB, San Jose scale, European red, and brown almond mite eggs, and fruit tree leafroller eggs. Peach twig borer and San Jose scale resistance has been documented in San Joaquin Valley peach orchards.

Azinphos-methyl – Most effective as an in-season material. (see navel orangeworm)

Esfenvalerate – 21 days PHI. This is a highly effective peach twig borer material when applied by ground during the dormant period. Used on 7% of the acreage by ground at 0.05 lb. a.i. per acre (1). It is also effective against other lepidopterous pests. This is the most economical material available and has low mammalian toxicity. The biggest drawback is it disrupts biological control of mites, often even when applied during dormancy (5). Esfenvalerate will also control navel orangeworm, (5), if used during the growing season but this material is very disruptive to the biological control of mites and scale, and should only be used during the growing season in an emergency situation. Resistance has developed in some growing areas to Esfenvalerate.

Phosmet – 30 days PHI. Effective on navel orangeworm, peach twig borer and other lepidoptera when used during growing season. Also used dormant for peach twig borer. It will control San Jose scale crawlers if crawlers are present. It is applied to 6% of the acres at an average rate of 3.0-lb. a.i. per acre (1). Phosmet can cause mite outbreaks but is not as disruptive as some other materials.

Carbaryl (see navel orangeworm) – Used late in season when other alternatives cannot be used because of longer PHIs.

Naled - 4 days PHI. Applied during the dormant period by ground to 1.5 % of the acreage at the rate of 1.5 lb. a.i. per acre, (1). Provides fair control, however resistance develops quickly to naled (16).

Chlorpyrifos - 14 days PHI. Historically, this material is used as a dormant spray for control of PTB with over 50 % being used for ant control. For control of PTB it is applied by ground during the dormant period to approximately 10% of the total acreage at an average rate of 1.5 lb. a.i. per acre (1). Cannot be used during the dormant period in the Sacramento Valley because damage to trees can result (5). Will also control lepidopterous pests when used post-bloom.

Methidathion - Primary use is for overwintering San Jose scale. No in-season use.

Permethrin – 7 days PHI. Applied by ground during the dormant period to 10% of the acreage at an average rate of 0.2-lb. a.i. per acre (1). This is the most economical material available and has low mammalian toxicity. The biggest drawback is it tends to disrupt biological control of mites, even when applied during dormancy. Will also control navel orangeworm if used during the growing season but this material is very disruptive to the biological control of mites (5) and should only be used during the growing season in an emergency situation.

2. Alternatives

Populations of PTB are present in most California orchards, but actual damage from PTB has been light in Merced and Stanislaus counties, according to recent studies by UCCE Advisors Lonnie Hendricks and Walt Bentley. They have found that PTB is not a consistently damaging pest in almonds in both conventional and more biologically managed orchards in these counties. This supports the conclusion that growers can eliminate an OP spray for PTB and still maintain quality yields in Merced and Stanislaus counties. PTB can be controlled during bloom with well-timed treatments of Bt (26). In most orchards, this spray can provide satisfactory control without further in-season treatments.

Spinosad is a newly registered chemical that is very effective against PTB. It can be used both as a dormant and in season spray, and is in the same cost range as an application of Chlorpyrifos. It is as effective as traditional OP sprays and is relatively safe for humans, with a low mammalian toxicity. It has been shown to be less toxic to some beneficial insects, but has not yet been shown to spare predators and parasites of mites and scale in almonds. While Bt is only toxic to lepidopteran (moth and butterfly) insects, and spares all other natural predators, Spinosad is a comparatively broad-spectrum insecticide. Spinosad is known as a "soft" pesticide because of its safety for humans, not its narrow range of insect toxicity. It should be noted that there are concerns about the cost of using Spinosad in comparison to Bt.

Another practice used by some growers is to apply a pyrethroid spray at a very low level at hull split in place of an OP insecticide spray.

3. Cultural Control Practices

No effective cultural controls for peach twig borer are known. However, there are varietal differences that can affect the infestation of PTB. Soft-shell varieties are more susceptible to damage from PTB.

4. Biological Controls

Numerous natural enemies attack PTB throughout the egg and larval stage. Among the most common are *Paralitomastix varicornis, Hyperteles lividus,* and the grain or itch mite, *Pyemotes ventricosus,* which feed on larvae in the hibernacula. The California gray ant has been found to be a significant predator of PTB in San Joaquin Valley peach orchards. Natural enemies can cause significant mortality and as less disruptive insecticides are utilized will probably play a more important role in regulating PTB numbers (2, 5). BIOS growers have tried to augment this natural process by releasing *Trichogramma planteri* that parasitize PTB eggs. Although no scientific studies have demonstrated that *Trichogramma* lowers worm damage at harvest, many growers believe they achieve good control by releasing additional wasps.

The primary biological control of peach twig borer relies on the use of *Bacillus thuringiensis* (Bt). The program calls for Bt treatments at the beginning and late bloom to take advantage of the fact that PTB does a considerable amount of feeding on leaves and stems before boring into new shoots (5). Bt does not harm PTB beneficial insects.

Bacillus thuringiensis (BT)- 0 days PHI. Applied at least twice per season by ground or air to approximately 25% of the acreage at the average rate of 0.1-lb. a.i. per acre (1). It has low mammalian toxicity, is selective for lepidoptera and is not harmful to wildlife or aquatic organisms. Timing of applications is critical and is often not effective during cold, wet springs. Applied at bloom or post-bloom.

Mating disruption has been used for PTB in more high value labor intensive crops such as peaches. Results have been variable and the cost of this program is currently too high for it to be widely adopted in almonds. This may change as better and cheaper formulations are developed.

5. Other Issues

Once considered one of the major almond pests, peach twig borer was controlled by the use of a dormant OP spray. Today growers can find many options which reduce the pesticide risk for controlling PTB and still be assured that the pest will not reach damaging levels. The use of Bt sprays, pheromone mating disruption, and careful monitoring help growers make informed decisions about how to treat their orchards and allow the natural predators to help with control. It should be noted that mating disruption may only work for growers using an area-wide program because of migratory behavior.

San Jose Scale, *Quadraspidiotus perniciosus*

Armored scales suck plant juices from the inner bark by inserting their mouthparts into twigs and branches. Infested branches stop growing and heavily infested branches and fruit spurs will die. San Jose scale can kill scaffolds. A small, gray shell that makes control difficult covers San Jose scale. If the shell covering is removed the small yellow body can be seen (2). Newly hatched nymphs move from under the shell and settle on branches and twigs. The best time to control scale is during the dormant period or in early season after hatching until the covering is well developed. San Jose scale has 3-5 generations per year. Heavy populations may reduce production by as much as 10% if left uncontrolled. **Monitoring:** Monitoring should begin with dormant sampling as in PTB. The same spurs collected for PTB can be used to monitor for SJS. By inspecting approximately 100 spurs for every 10 acres, the population of SJS may be determined. Do not count the number of SJS on a single spur, count only the spur itself as having a SJS population. If 10% or more spurs have SJS, then a dormant spray may be necessary. If 10% or less of the dormant spurs have SJS, then a dormant spray may not be necessary. If there is question, then re-sample in a few days and re-evaluate if a dormant spray is necessary. The population of the san jose scale parasites may also be determined and recorded at this time. If the san jose scale has a distinct rounded hold in the shell, then the scale may be parasitized by *Aphytus sp.* or *Prospaltella sp.* During the season, look for the presence of scales on twigs and branches (2) and check fruiting spurs. Scale pheromone traps and sticky traps are useful monitoring tools for timing decisions only. Pheromone traps, which captures males, should be placed on the north side of the tree approximately 4-6 feet above ground and away from sprinklers. Traps should be checked weekly and lures changed every 4 weeks. Weekly assessments of the number of san jose scale and the number of the san jose scale parasite, *Aphytus sp.* or *Prospaltella sp.*, should be recorded. UC IPM Entomologist Walt Bentley has found good correlation between sticky tape catches and trap catches.

1. Chemical Controls

Because armored scales spend most of their life protected beneath the scale covering correct timing and spray coverage is important.

Methidathion - 80 days PHI. The most effective material for armored scales. Applied primarily dormant to 10.5% of the acres at the rate of 2.0-lb. a.i. per acre (1). Will help control peach twig borer (5).

Dormant Oils – 0 days PHI. Applied during dormant to 40% of the acreage at the average rate of 3.5 gallons per acre (1). Will also control overwintering mite eggs. Controls younger scales and gray cap stage.

Chlorpyrifos - 14 days PHI. Historically, this material is used as a dormant spray for control of PTB with over 50 % being used for ant control. For control of PTB it is applied by ground during the dormant period to approximately 10% of the total acreage at an average rate of 1.5 lb. a.i. per acre (1). Cannot be used during the dormant period in the Sacramento Valley because damage to trees can result (5). Will also control lepidopterous pests when used post-bloom.

2. Alternatives

Dormant oils used during the early part of the dormant period have been shown effective in controlling populations of San Jose scale when no broad spectrum insecticides are used during the growing season. It is important to use higher label rates of oil with good coverage. In most cases, organophosphate insecticides are not needed to control this pest.

3. Cultural Control Practices

Prevent dust, which interferes with parasites.

4. Biological Controls

Several natural enemies tend to hold armored scale populations in check. Two predaceous beetles, the twice-stabbed beetle, *Chilorcorus orbus* and *Cybocephalus*

californicus often occur in large numbers and can keep low to moderate populations in check. (1) Two parasitic wasps, an *Aphytus sp.* and *Prospaltella sp.* also are effective at keeping populations of SJS down. Eliminating the use of dormant and in-season broad-spectrum sprays allows these naturally occurring parasites to survive and help keep scale under control.
If an OP dormant spray is not applied, then it is important during the dormant season to monitor for the presence of san jose scale by examining pruned branches-to see if there is sufficient scale population to warrant treatment. During the growing season, pheromone traps for san jose scale can provide an assessment of scale abundance and scale parasites. Scale parasites can be detected on the traps throughout the season.

5. Other Issues

The use of dormant oils has been shown to be effective in controlling san jose scale. Recent work with BIOS has shown that growers in Colusa, San Joaquin, Stanislaus, Merced, and Madera counties can eliminate a dormant spray of OP insecticides without damaging levels of scale occurring.

Ants
Pavement Ant, *Tetramerium caespitum*
Southern Fire Ant, *Solenopsis xyloni*

Ants are significant pests of almond, particularly in central and southern areas of the San Joaquin Valley. As the use of drip irrigation and mini-sprinklers increase, ants will probably increase in importance in other areas (16). The pavement ant is 0.13 inches long, brown and covered with coarse hairs. It prefers to nest in sandy or loam soils. The southern fire ant is 0.1 to 0.25 inches long, has an amber head and thorax with a black abdomen. Ants are principally a problem after almonds are on the ground and damage increases in relation to the length of time they remain on the ground before being picked up. Ants can completely hollow out nutmeats leaving only the pellicle (2, 5). Damage is also lower on varieties with good shell seals but can exceed 20% in susceptible cultivars.
Monitoring: Potential ant damage can be estimated by counting the number of colonies in 5000 sq. feet (5). Ant traps consisting of PVC pipe, closed on both ends with 3-4 holes drilled into the middle of the pipe, baited with either almonds or hot dogs can be placed in the orchard, next to a tree, and checked weekly for ant pests. Ant traps can be placed near the single tree which contains the traps for PTB, NOW, and SJS so that monitoring can take place in one area as these traps do not interfere with each other.

1. Chemical Controls

Chlorpyrifos – 14 days PHI. This is currently the most effective registered material for control of ants. Applied to the orchard floor at the rate of 2-lb. a.i. per acre with approximately 10% of the acreage being treated in this manner (1). When ant colonies are concentrated on berms 6-10 ft. band treatments are effective.

Permethrin – (See peach twig borer). Not very effective. Quick knock down, but no residual activity.

Abamectin – Newly registered. Procedures are being refined to improve efficacy.

2. Alternatives

Utilizing chemical control as bait or spot treatments eliminates the need for broadcasting, or spraying the entire orchard, with chemicals.
Additional products being tested on ants include(Knack) pyriproxyfen, and (Amdro) hydramethylnon. Registration on these products is pending.
Research continues on the insect growth regulator (IGR), (Logic) phenoxycarb. The IGRs are slow to act, and may take three, four, or five weeks before a substantial reduction in populations occur. (5)

3. Cultural Control Practices

One of the most important variables to consider with ant control is to identify the type of ants in the orchard, since only the southern fire ant and the pavement ant feed on almonds.
Removing nuts from the orchard floor as soon as possible after shaking can minimize ant damage. (4)
Where ants are the primary pest, leaving the almonds on the tree for as much drying as possible will help prevent ant infestation. This allows picking the nuts from the ground without a delay in drying . Also, scheduling the shaking of heavily ant infested blocks late in the season to keep the nuts on the tree as long as possible may help ant control. (6)
The soft-shell varieties such as Nonpareil and Merced can be heavily damaged by ants. Hard shells such as Mission, Butte, and to some extent the Carmel_cultivator is not as susceptible to ant damage. It is not necessary to treat for ants in a hard shell orchard. (6)
Damage is also lower on varieties with good shell seal. (4)

4. Biological Controls

Currently none are available.

5. Other Issues

Ant damage to almonds continues to be a difficult problem for farmers to manage. The primary factors which influence damage include the population of ants in the orchard and the length of time the nuts are left on the ground to dry. Finding ways to harvest ant infested blocks later in the season, applying insecticides as a spot treatment, and looking to new reduced risk options will be important in dealing with ant populations in almonds.

Mites
Two-spotted Mite, *Tetranychus urticae*
Pacific Mite, *Tetranychus pacificus*
European Red Mite, *Panonychus ulmi*
Brown Almond Mite, *Bryobia rubioculus*

Although European red mite can build up to high numbers, they seldom reach damaging populations and serve as a food source for predators. However, both two-spotted and pacific mites can cause almost complete defoliation that exposes trees and fruit to sunburn, reduces fruit size and sugar, and can interfere with harvest (2). Pacific mite is the dominant species in the San Joaquin Valley and two-spotted mite predominates in the Sacramento Valley. However, over the years pacific mite has become more common in the Sacramento Valley, possibly due to the use of Propargite which is more effective on two-spotted mite. Pacific and two-spotted mites over-winter as adult females in the trees or on the orchard floor. Both species are favored by hot, dry conditions and as the weather becomes warmer, they increase in numbers and move throughout the tree (2). Severe defoliation early in the season can cause a 25% reduction in yield the following year (16). As the season progresses, the potential for direct damage decreases.
Monitoring: Monitoring begins in the dormant season, December-January, with sampling of the spurs. As with PTB and SJS, the same dormant spurs can be monitored for mites. Do not count the number of mite eggs per spur, only the number of spurs with mite eggs present. The eggs are red and will be found singly or in clumps. If more than 10% of the dormant spurs have mite eggs present, then a dormant spray may be necessary. If less than 10% of the dormant spurs have mite eggs, then a dormant spray may not be necessary. If there is a question pertaining to the number of spurs with eggs, resample again in a few days and re-evaluate. During the season, mites can be monitored by leaf brushing or presence/absence sampling beginning in July and continuing weekly until harvest(5).

1. *Chemical Controls*

Propargite - 21 days PHI. Applied post-bloom by ground to 27% of the acres at the rate of 1.5 lb. a.i. per acre (1). Propargite fits well in an IPM program and is the most effective material available. Does not disrupt biological control of mites.

Fenbutatin-oxide - 14 days PHI. Applied post-bloom by ground to 10% of the acres at the rate of 0.5-lb. a.i. per acre (1). Does not disrupt biological control of mites and aphids. Fits well in an IPM program. Does not work well in cool weather.

Clofentezine - 30 days PHI. Applied post-bloom as a preventative treatment by ground to 6% of the acres at the rate of 0.1-lb. a.i. per acre as a preventative treatment (1). Does not control high mite populations. Does not disrupt biological control of mites is not a problem in almonds. Fits well in an IPM program.

Narrow Range Oils. - 0 days PHI. Use data not available. Can be applied post-bloom by ground at the rate of 4 gallons per acre (16). This is a selective material. Effective acaricides when mite populations are low and predators are present. Oils must be used with caution because of potential phytotoxicity if trees are stressed or dry (5). Oils fit well in the IPM program if predator mites are present. **Oil, when used alone, does not**

control peach twig borer. A drawback with oils is they contribute to air pollution because of hydrocarbon volatilization.

Abamectin – Must be used early season when trees are actively growing. No use data available.

Pyramite – disruptive and knocks out predator mites. This material can control mites and can be used closer to harvest.

2. Alternatives

European red mite and brown mite can be controlled with an application of dormant horticultural oil. In-season alternatives are not available.

3. Cultural Control Practices

The main cultural control for mites is to avoid the use of in-season broad-spectrum pesticides for NOW and PTB.
Monitoring for mites twice a week, when the weather is warm, is important to determine if mite populations are building. If there are large numbers of predator mites (primarily the western predator mite) then chemical controls may be held back to give the predator mites a chance to build up.
Water stress contributes to mite flare-ups. According to Kern County UCCE Farm Advisor, Mario Viveros, it is not always easy for growers to prevent water stress. Summer time water stress can encourage high mite populations to build up late in the season. These large populations will overwinter and come back strong the next season. He recommends that leaves should not be water stressed during June to help avoid mite problems. (25)

4. Biological Controls

Mites are generally not a problem in almond orchards where broad-spectrum insecticides are avoided. When an in-season broad-spectrum insecticide is used for NOW or PTB control, the natural predators that usually keep mites under control are also killed and the mite populationincreases dramatically. A miticide is then usually needed to avoid economic damage. If the in-season use of the broad-spectrum insecticide is avoided, then mites are usually not a problem. Synthetic pyrethroids especially can result in serious mite outbreaks because of long residue or bark reducing bredaton mites.
Predators are important in regulating mite populations. The most dependable predator is the Western Orchard predator mite, *Galandromus occidentalis,* which, if not disturbed by pesticides applied for other pests, can usually keep populations below damaging levels in well managed orchards. *G. occidentalis* is resistant to most organophosphates and insect growth regulators used for navel orangeworm and PTB control but extremely susceptible to synthetic pyrethroids and carbamates (5). It should be noted that the predatory mites bred and released by Dr. Marjory Hoy at UCB were resistant to organophosphates, carbaryl, and sulfur. It is not known if most of the predators found today still retain those

characteristics. Other important predators include six-spotted thrips, minute pirate bug, and a small beetle, the spider mite destroyer.

5. Other Issues

It may be that with a decrease in the use of in-season OPs and synthetic pyrethroid sprays, the damaging mite pests will be held in check by their natural predators. As growers become more aware of the cultural practices that can trigger mite outbreaks, they will be better prepared to manage orchard conditions to prevent mite flare-ups. The use of a planted cover crop or managed resident vegetation can help provide food and habitat for mite predators. It may take several years without the use of pesticide sprays for the population of beneficial insects to develop.

E. MINOR OR OCCASIONAL INSECT PESTS

These pests are usually not an economic problem in most orchards. An insecticide spray is not generally used to control these pests unless they become serious economic concerns.

- Eriophyid Mites
  - Peach Silver Mite, *Aculus cornutus*
- Lepidopterous Wood Boring Insects
  - Peachtree Borer, *Synanthedon exitosa*
  - American Plum Borer, *Euzophera semifuneralis*
- Leaffooted Bug, *Leptoglosssus clypealis*
- Leafrollers
  - Oblique-banded Leafroller *Choristoneura rosaceana*
- Oriental Fruit Moth, *Grapholita molesta*
- European fruit leucanium
- Woodboring Beetles
  - Shothole Borer, *Scolytus rugulosus*
  - Branch and Twig Borer, *Polycaon confertus*
  - Pacific Flatheaded Borer, *Chrysobothris mali*

F. WEED CONTROL

In addition to problems at harvest, weeds can cause a multitude of other problems in almond orchards by reducing the growth of young trees because they compete for water, nutrients, and space. Weeds also increase water use, cause vertebrate and invertebrate and other pest problems, and may enhance the potential for diseases such as crown rot. Most orchards are no-till, requiring the use of herbicides and/or mowing to control weeds. The increasing use of more efficient low-volume irrigation systems has increased the need for selective pre-emergence herbicide use in drip, microsprinkler, and sprinkler-irrigated orchards. Pre-emergent herbicides are generally used only in the tree row. This reduces the total amount of herbicides and prevents the surface roots in the tree row from being damaged by cultivation equipment. By treating the tree row only, 25% to 33% of the total acreage is treated. Pre-emergence and post-emergence, or combinations of pre- and post-emergent herbicides are often used between tree rows. Soil characteristics have an effect

on the weed spectrum (often 15-30 species per orchard), the number of cultivations and irrigations required, and the residual activity of herbicides. Irrigation methods and the amount of irrigation or rainfall effects herbicide selection and the residual control achieved.
Almond orchards may benefit from carefully managed resident vegetation or a cover crop. A well-maintained ground cover can help increase water infiltration, increase orchard accessibility after rain or irrigation, reduce soil compaction, maintain or increase soil organic matter content, provide supplemental nitrogen, cool the orchard, reduce dust, and provide habitat for beneficial insects (5, 28). **Monitoring:** Treatment decisions and herbicide selections are based on dormant and early summer weed surveys.

1. *Chemical Controls*

Glyphosate - 3 days PHI. Most often used herbicide (16). Applied during the dormant, pre- and/or post-bloom by ground. Often applied at low rates several times during the season. This accounts for the fact that use data indicate this material is applied to >100% of the acreage. Annual use rate averages 0.75 lb. a.i. per acre (1). Nonselective systemic used for a broad range of weed species. Effective anytime on emerged, irrigated, rapidly growing, non-stressed weeds, but activity is slower in lower temperatures. Best material available for most perennial weeds. Cannot eradicate field bindweed or nutsedge. Not effective on some broadleaf weeds at older stages of growth (malva and filaree). Continued use of this material leads to a shift of species and selection of tolerant species (16). Light activated spray technology has reduced the amount of material applied when weed cover is low by 50 to 80%.

Oxyfluorfen - Apply following harvest up to February 15. Applied by ground one time per season on 41% of acreage at an average rate of 0.2-lb. a.i. per acre (1). Selective broadleaf herbicide effective as a pre- and post-emergent material. Particularly useful when combined with glyphosate to increase efficacy on various broadleaf weed species and to prevent broadleaf species shifts with glyphosate. Oxyfluorfen is the only effective material for malva (16).

Simazine - 21 days PHI. Applied anytime to bare soil or in combination with glyphosate by ground one time per season on 14.2% of the acreage at an average rate of 0.61 lb. a.i. per acre (1). Pre-emergence herbicide of most annual grasses and many broadleaf weeds. Effective when combined with translocated herbicide such as glyphosate or the contact herbicide paraquat, and a broadleaf pre-emergence herbicide as in oxyfluorfen. Typically used for down the row treatment to maintain clean row for irrigation emitters and season long weed suppression (5). Simazine is the only material effective on fleabane and horseweed. This product is weak in controlling grasses (16).

Paraquat - 0 days PHI. Applied by ground one or more times per season to 30% of the acreage at an average rate of 0.73 lb. a.i. per acre (1). Nonselective post-emergence material used for quick burn-down of most weed species. This product is less effective against perennials that will regrow with vigor, e.g., bermudagrass, dallisgrass, johnsongrass, and bindweed (16). Most effective when used on early spring or winter growth of annual grass species in combination with pre-emergence herbicides.

2,4-D - 60 days PHI. Applied as a directed spray post-bloom by ground one or two times to 17.5% of the acreage at the average rate of 1.78 lb. a.i. per acre (1). Post-emergence systemic herbicide selective for most broadleaf annual weeds. Provides partial control of field bindweed. Useful for controlling troublesome perennials (16).

Oryzalin - 0 days PHI. Applied at 2-4 lb. as pre-emergence in the tree strip by ground one time per season on 17.5% of the acreage at the average per acre rate of 1.8 lb. a.i. per season (1). This product is a pre-emergence selective herbicide most effective on annual grass species and numerous broadleaf annuals which is. Very safe for young or newly planted trees and on sandy or sandy loam soils (16). It is used to maintain control in strips down the row. Often used in combination with other pre-emergence herbicides.

Norflurazon - 60 days PHI. Applied pre-bloom by ground one time per season on 9% of the acreage at the rate of 1.06 lb. a.i. per acre (1). Pre-emergence selective herbicide similar to oryzalin, but is effective on more annual broadleaf and grass species. Can suppress yellow nutsedge or bermudagrass when used year after year (16). Can cause minor damage to younger trees or those planted on sandy or sandy loam soils. Usually used on new plantings. Norflurazon is_primarily a grass control material (16).

Trifluralin - 0 days PHI. Applied pre-bloom by ground one time per season on 1.25% of the acreage at the rate of 1.27 lb. a.i. per acre (1). Pre-emergence selective herbicide for annual grasses. It must be combined with broadleaf herbicides and incorporated promptly for best results. Used on new plantings or established orchards as a strip treatment. Suppresses bermuda, johnson and dallis grass rhizomes (16).

Napropamide - 0 days PHI. Applied pre-bloom one time per season on 2% of the acreage at the rate of 4-lb. a.i. per season in the tree row (1). Pre-emergence herbicide effective on annual grasses and several annual broadleaves (16). Must be applied and incorporated with irrigation or rain within seven days. Very effective in maintaining weed free strips down the row. May be applied in late winter with glyphosate for late burn down. Used on bearing and non-bearing trees.

Pendimethalin - Non-bearing trees only. Applied pre-emergence by ground one time per season to 1.8% of the acreage at the rate of 2.0-lb. a.i. per acre. Effective on annual grasses and some broadleaf weeds (16).

EPTC – 16 days PHI. Applied to 1.07% of the acreage at an average rate of 2.32 lb. a.i. per acre. Applied pre-emergence by sprinkler irrigation after orchard floor is prepared for harvest to prevent re-growth of weeds and grasses. Very little used because the alternative materials are better (16). Does control nutsedge.

2. Alternatives

There are current practices being implemented or researched that may reduce the amount of herbicides used in almond orchards. Planting selected annual cover crops in orchard middles, reducing the width of the herbicide treated strip, hand hoeing, or flaming are all methods currently being utilized by growers who want to reduce their herbicide use.

Encouraging the use of post emergence herbicides whenever possible to avoid runoff and delaying applications of soil sterilants until most of the winter rains have fallen will help prevent ground water contamination (Prather, 1998)

3. Cultural Control Practices

Complete tillage is a little used option in almonds. It is decreasing in use and has several drawbacks. It is expensive to own and operate the machinery needed, destroys the soil structure, can create dust and causes soil compaction.

4. Biological Controls

The use of cover crops or managed resident vegetation in orchards can be used effectively to out-compete certain undesirable species. They can benefit the soil by adding organic matter, nitrogen and improving water infiltration. Planted cover crops also serve as hosts for aphids and mites that provide alternative prey for beneficial insects such as parasitic wasps, lacewings, and labybird beetles. Cover crops can reduce the dust and lower the temperature in an orchard thus helping to control outbreaks of mites.
The almond PMA project helps growers experiment with planted cover crops. Managed resident vegetation or planted cover crops can prevent soil erosion and in the process trap contaminants such as pesticides and herbicides and prevent their movement as surface runoff into streams and rivers. Cover crops and strip plantings are both practices that are being studied at the PMA demonstration sites. Winter runoff water will be gathered from the demonstration plots to evaluate the movement of pesticides and residues found. Orchards utilizing cover crops and native vegetation may require more water. This key issue will be examined as part of the project by measuring soil moisture and water infiltration rates in the cover crop and non-cover crop soils.
Dr. Frank Zalom, UC IPM is conducing orchard runoff studies to determine the off-site movement of pesticides and fertilizers in several of the PMA orchards.

5. Other Issues

The use of post-emergence chemicals, reducing strip width and out-competing some weeds are being considered more frequently in controlling weed problems in a more biological system.
Growers have expressed concerns that a planted cover crop may give them too much residue to be managed at harvest. Some data suggests that some growers have found this practice to be useful. Almond growers in the BIOS program have been using planted cover crops for many years. BIOS growers surveyed in 1997 did not report a problem with planted covers interfering with harvest. Using an effective mowing strategy takes some planning, but some growers find the added benefits of improved water infiltration, weed suppression, dust control, improved orchard access in winter, reduced orchard runoff and increased soil organic matter are worth the effort.

G. DISEASE CONTROL

Almonds are subject to numerous diseases that reduce yield and quality of the crop and sometimes weaken and kill trees. For many of the more serious diseases, the only management tools available are preventative treatments that protect flowers, leaves and fruit prior to infection (9).
Disease of almond can be divided into three groups based on the area of infection in the tree: root and crown infections, leaf and fruit infections, and vascular tissue infections. In general, there are no chemical treatments for disease that attack the root and crown. Prevention of infection and prevention of the environmental conditions that favor infection are the only management practices available. Root and crown diseases will not be covered in this documentation, although Phythopthera root and crown rot is a major problem. Only the diseases of leaf and fruit tissues will be covered because they are the main diseases controlled by chemicals.

For all the major fungal and bacterial diseases, reduced risk alternatives involve prevention of the disease by:

1. selecting resistant varieties and rootstocks
2. planting in areas without previous disease problems (some diseases occur on multiple crops)
3. avoiding planting in low areas or with a standing water problem
4. using an adjusted irrigation system that does not wet the tree leaves
5. avoiding prolonged irrigations that allow standing water
6. practicing good nitrogen fertilizer management-excessive nitrogen fertilization can promote some diseases, such as hull rot
7. using management techniques that promote strong and healthy trees that are more resistant to disease
8. avoiding transfer of disease organisms from one area to another on equipment or personnel.

For other specific pre-planting recommendations please refer to the UC IPM for Almonds manual.

Chemicals used for disease control are also based on the concept of prevention. Once the disease symptoms occur, the disease organisms cannot be eliminated. Some chemicals can control symptoms and reduce economic damage. When these chemicals are used, certain practices can reduce the possibility of negative effects on worker and environmental health.

These are referred to as best management practices (BMPs) and they are as follows:

1. proper mixing and loading of pesticides
2. proper sprayer calibration
3. spray drift avoidance
4. proper container and waster water disposal.
5. planting vegetation strips along waterways and creating berms to contain water on site.
6. use of a planted cover crop or managed resident vegetation can be helpful in reducing winter runoff. (21)

Brown Rot

Monilinia laxa or Monilinia fructicola

Brown rot can be a serious problem on almond and other stone fruits such as cherry, peach and apricot. Butte, NePlus Ultra, Carmel, Thompson, and Mission cultivars are often severely blighted, whereas Nonpareil, Price, and Fritz usually sustain less damage (6). The disease occurs in most almond producing areas in California and is worse when rains or fog occur during bloom. The fungus overwinters in twig cankers or in dead blossom parts. In early spring the fungus produces sporodochia where spores are produced. Spores are wind-disseminated to blossoms. Infected flowers wither, collapse, and remain attached to the fruit spurs. The fungus grows from the blossom into fruiting spurs or twigs to form cankers. The nearby leaves, and often, the entire twig beyond the site of infection die. Almost complete crop loss can be experienced on susceptible cultivars when rain persists during bloom (16). Damage is often experienced several years after a severe infection because of the loss of fruiting spurs.

1. Chemical Controls

Control of brown rot depends on protecting blossoms from infection from popcorn stage through bloom (5).

Benomyl - 50 day PHI. Excellent brown rot material. Labeled for 0.5-0.75 lb. a.i. per acre. Applied during bloom by ground or air to 20% of the acreage at an average rate of 0.5-lb. a.i. per acre (1). Strains of brown rot fungi have been found to be resistant in some California orchards (5). Material is good to excellent on leaf blight (when combined with Captan) jacket rot, and scab (17). Resistant strains of *Botrytis cinera*, have been reported in California on crops other than almond and stone fruits. Resistant strains *Cladosporium carpophilum,* have been reported on other crops but not in California. Not effective for shot hole management and Anthracnose pathogen is mostly insensitive to benomyl (12).

Iprodione - (5 weeks after petal fall). Good brown rot material, excellent when combined with oil (1-2% summer oil), however, water quality can seriously effect performance (17). Labeled for 0.5-lb. a.i. per acre. Applied during bloom by ground or air to 55% of the acreage at an average rate of 0.5 lb. a.i. per acre. Also controls jacket rot and is moderately effective on shot hole.

Thiophanate-Methyl - (cannot be applied after petal fall). Excellent for brown rot, jacket rot and leaf blight when combined with Captan (17). Labeled for 0.75-1.5 lb. a.i. per acre. Applied during bloom by ground or air to 8.8% of the acreage at an average rate of 0.7-lb. a.i. per acre (1). Organisms resistant to benomyl are also probably resistant to this material. Not effective for shot hole management. Anthracnose pathogen is mostly insensitive to thiophanate-methyl (17).

Myclobutanil - 90 days PHI. Good control of brown rot and leaf blight. Some activity on anthracnose when combined with Captan (17). Labeled for 0.15-0.2 lb. a.i. per acre. No record of use in 1995.
Strains of brown rot resistant to benomyl and thiophanate methyl have been found on almonds, but resistance is not widespread. One application of a contact fungicide or thiophanate methyl at pink bud is sufficient in most orchards.

Captan 50 wp at 8 lb. Be sure to note label for preharvest interval which varies depending on formulation and if hulls are to be fed to livestock. Do not apply in combination with, immediately before, or closely following oil sprays.

Maneb 80 6-8 lb. Do not apply more than a32 lb. of product /acre/season.
145 PHI

2. Alternatives

There are currently no known effective alternatives.

3. Cultural Control practices

Fungus diseases are closely linked to weather conditions and wet springs increase the possibility of brown rot. Consider the history of disease in the orchard, general weather patterns, cultivar susceptibility, and control of other diseases when selecting fungicides and timing applications. Judicious and limited use of fungicides minimizes the risk of developing resistant strains. (6)

4. Biological Controls

There are no known biological controls.

5. Other Issues

The lack of suitable options in the treatment of fungal diseases is a major barrier in a reduced risk system. Use of the BMPs aimed at protecting water quality and worker safety should be employed when dealing with almond diseases.

Anthracnose
Colletotrichum acutatum

This disease was not considered a problem in California until the early 1990s. The fungus is now found in all major almond growing regions from Butte County to Kern County and is considered a major threat to the industry. Spores of the fungus are produced on all infected tissues during wet conditions and are disseminated by water transfer.

Development of anthracnose is favored by extended, warm, rainy weather. All cultivars appear to be susceptible to anthracnose but there are differences in susceptibility (12). The fungus overwinters in dead wood or in mummified fruit that remain attached to the tree. Blossoms, leaves, and fruit can be infected. Infected blossoms become blighted, similar to brown rot blossom blight but with orangish spore droplets on the floral cup. Leaf infections are yellow irregular lesions that begin at the leaf margin or tip and advance toward the middle of the leaf. In fruit, infections, symptoms include orangish, circular, sunken lesions in the hull of young fruit. Symptoms are generally observed 2-3 weeks after petal fall as shriveled fruit that become light rusty orange and appear like almond "blanks." In older fruit, symptoms are similar, but profuse gumming often occurs around the infection that continues to develop, destroying the endosperm and killing the embryo. Diseased fruit eventually die, become mummified, and remain attached to the tree where the fungus continues to grow into the almond spur or fruiting branch tissue. The result of this advanced state of host colonization is branch dieback. Nuts remain susceptible throughout the season and when conditions are favorable (rain) can become infected at any time during the season (12). This is an extremely serious disease that requires multiple applications of suitable materials for control. Up to seven applications in research plots have failed to provide complete control of this disease (13). An increase in the fungicide treatments for management of this disease could lead to serious resistance problems in almonds.

1. Chemical Controls

Fungicide treatment is currently the most effective control strategy for managing this disease. In orchards that have a history of anthracnose. University of California Guidelines suggest applying fungicide sprays beginning at pink bud and repeat every 10 to 14 days if rains persist (5). Treatment is recommended as long as rains persist. Dormant mummy removal and pruning out dead wood reduces inoculum and severity of disease. Low-angle irrigation that reduces canopy wetness also reduces severity of disease (12).

Azoxystrobin - Proposed label rate is 12-16 fl oz per acre. Very effective against anthracnose, scab, and Alternaria leaf spot, moderately effective against shothole and brown rot blossom blight. Also shown to be effective against peach rust (17).

Tebuconazole - 45 days PHI. Not registered. Proposed labeled rate is 4-8 fl. oz. per acre. In experimental trials, very effective against anthracnose. Excellent on brown rot. Moderately effective on leaf blight. Also shown to be very effective on peach rust. Not effective for shot hole or scab (17).

Propiconazole - 90 days PHI. Not registered, although Section 18's have been in place the last three years. Labeled rate 2-4 fl. oz. per acre. Excellent on brown rot. Moderately effective on leaf blight. Not effective for shot hole or scab (17).

Chlorothalonil - Not registered. (Restricted to bloom and petal fall). Labeled rate 3.0-lb. a.i. per acre. In experimental trials, effective as a protective treatment against anthracnose. Also effective as a protective treatment in experimental trials against brown rot and shot hole (17).

Captan - Control of anthracnose is moderate and variable. Important resistance management tool when used in combination with other materials (11).

Myclobutanil - (Restricted to bloom). Moderately effective on anthracnose. (see brown rot).

Trifloxystrobin - Proposed label rate is 1.5-3 fl. oz. per acre. Very effective against anthracnose. Other diseases not evaluated, (17).

2. Alternatives

There are no known alternatives for these fungicides.

3. Cultural Control Practices

All varieties of almonds are susceptible to this fungus, but Merced, Monterey, NePlus, Carmel, Price, Butte, and Thompson are highly susceptible. Fritz, Harvey, Mission, and Padre can also be badly infected. Nonpareil can show some infection, but is probably the least affected variety. (10) Since this is a relatively new disease, it is possible that cultural controls may be developed to help combat anthracnose.

4. Biological Controls

There are no known biological controls.

5. Other Issues

Anthracnose fungus has been a widespread disease problem in almonds since 1995. It can be a severe nut and shoot killer in wet years, yet it will nearly disappear in dry springs. Persistent fungicide treatments are the most important control strategy. Alternating materials may help to control the fungus as well as pruning out diseased wood to reduce inoculum

Shot Hole

Wilsonomyces carpophilus

Shot hole attacks both leaves and young fruit and can result in defoliation or premature nut drop. Infection of young fruit can cause fruit drop but infections on older fruit do not develop deep into the hull. Shot hole survives on infected twigs and as spores in healthy buds. Spores are moved by water to new sites; prolonged periods of wetness, either due to rain or sprinkler irrigation are required for the disease to develop. Shot hole can cause losses in yield, defoliation, and weakened trees (11). Almost complete defoliation can occur when rain persists throughout the spring, resulting in a reduction in photosynthesis and weakening of the trees.

1. Chemical Controls

Contact fungicides serve as protectants, not eradicants, and provide control only if they are applied so foliage and fruit are completely covered before a wet period (6).

Captan - (see brown rot). Provides good control of shot hole.

Iprodione - (see brown rot). Control of shot hole is good but variable (water quality can seriously effect performance).

Ziram - Cannot apply later than 5 weeks after petal fall. An excellent shot-hole material. Provides good control of scab and leaf blight but is weakly effective on brown rot (11). Applied by ground or air to 46% of the acreage at an average rate of 5.6-lb. a.i. per acre (1).

Maneb - 145 days PHI. Labeled for 1.5 qt. per acre. An effective shot-hole material and provides good control of scab. Weakly effective against brown rot (17).

Azoxystrobin - (see anthracnose).

2. Alternatives

There are no known alternatives.

3. Cultural Control Practices

The fungus survives on infected twigs and as spores on healthy buds. Spores are moved by water to new sites; prolonged periods of wetness, either due to rain or sprinkler irrigation, are required for the disease to develop. It is important to manage the angle of sprinkler irrigation so that leaves are not repeatedly wet.
Monitor orchard in fall and spring for shot hole lesions and fruiting structures. If present, in leaf lesion in fall, there is high risk of shot hole development the following spring and a petal fall treatment should be applied. Continue to monitor leaves in spring for lesions until wet weather is no longer a problem.
It has been shown by UCCE Farm Advisor Brent Holtz that the soft-shell varieties are more susceptible to shot hole than the harder shelled nuts. He has found that growers can be successful at combating shot hole by spraying only those rows with soft-shell varieties.

4. Biological Controls

There are no known biological controls.

5. Other Issues

Some cultural practices may help reduce the incidence of shot hole, but weather conditions may create unavoidable situations where the fungus is very active. Use of the BMPs aimed at protecting water quality and worker safety should be employed when dealing with almond diseases.

MINOR DISEASES

The following are considered minor diseases in almonds. Many are not economically damaging while others are controlled with chemical treatments applied to control brown rot, shot hole or anthracnose.
Green Fruit Rot or Jacket Rot
Monilinia spp. or
Botrytis cinerea, or
Sclerotinia sclerotiorum
Scab
Cladosporium carpophilum
Leaf Blight
Seimatosporium lichenicola
Alternaria Leaf Spot
Alternaria alternata
Leaf Rust
Tranzschelia discolor
Bacterial Canker and Blast
Pseudomonas syringae
Armillaria Root Rot
Armillaria mellea
Crown Gall
Agrobacterium tumefaciens
Root and Crown Rot
Phytophthora spp.
Ceratocystis Canker
Ceratocystis fimbriata
Verticillium wilt
Verticillium dahliae

H. OTHER PESTS

Nematodes

Lesion Nematode, *Pratylenchus vulnus*
Ring Nematode, *Criconemella xenoplax*
Root Knot Nematode, *Meloidogyne spp.*

Plant parasitic nematodes are microscopic roundworms that feed on plant roots of most plants including almonds. They live in soil or within the cortical tissues of the roots. The extent of the damage caused by nematodes in almonds depends largely on the density of the nematode population, soil conditions and rootstock selection. In situations where tree growth has been visibly impaired by the second year, the affected trees may never overcome the nematode problem. Symptoms of a nematode infestation include lack of vigor, small leaves, dieback of twigs and a sparse root system, particularly the lack of small feeder roots. Root galls are an indication of root knot nematode.

Ring nematodes spend their lives in soil feeding on roots. Feeding by ring nematodes stresses trees and makes them more susceptible to bacterial canker (*Pseudomonas syringae*). Ring nematode is common in sandier soils of the northern San Joaquin Valley, but also along fans of old river tributaries further south.

Dagger nematodes are most common in northern California soils. They also occur frequently in other production areas but scientists do not expect this species to cause tree damage unless a damaging ringspot virus is also present or the population is large, more than 400 per pint of soil (6).

Root lesion nematodes damage roots by moving through cortical tissues and feeding in these areas. Among first-leaf trees, damage due to the replant problems and the lesion nematode can be severe. Stunted trees occur within irregular, circular-shaped areas across the orchard. Among older plantings damage is barely discernible. Fruit size and quantity are reduced with only slight apparent stunting in overall tree growth. Yield and size data of plum on both peach and plum rootstocks indicate up to a 16% reduction in marketable fruit, with peach rootstocks being more adversely affected than plum. Similar rootstocks are used in almonds and similar reductions in yield would be expected.

Root knot nematodes take up a single feeding site within a root where they remain for their entire life. Some legumes grown for cover crop on the orchard floor provide an excellent habitat and food source for root knot nematode. Unfortunately many cover crops, including clovers do not show obvious symptoms of root galling. Nemaguard rootstock is resistant to root knot nematode and widely planted particularly in the San Joaquin valley (6).

Viruses are not a problem with certified virus-free *Prunus* rootstocks. If nurseries ever begin producing stock from nematode infested sites because a suitable fumigant is unavailable, viruses will become a significant problem.

1. Chemical Controls

Post-plant Treatments

There is one California-registered post-plant nematicide for bearing almonds. Enzone has effectiveness against the ectoparasitic ring nematode (3).

Pre-plant Treatments

Pre-plant fumigation is common in replant situations. Nematode numbers are greatly reduced for as long as 6 years by fallowing 1 or 2 years and then fumigating prior to replanting. The fumigation serves the important function of killing all the remaining roots within the surface 5 feet of soil profile. Without fumigation these roots remain alive two years after the old trees have been removed and the soil deep-ripped. Few growers could afford to idle their land for the 4 to 5 years necessary to achieve adequate relief from the replant problem plus root lesion nematode (3).

Methyl Bromide is used as a pre-plant treatment when replanting into soils previously in orchard crops. It is applied one to two feet deep, usually with a plastic tarpaulin stretched over the field surface. In order to save on costs, growers in some regions may treat only the planting strips or the individual planting sites at approximately 100 lb. per acre, with or without use of a tarp. There are no effective post-plant nematicides and no rootstocks are known to be resistant to root lesion nematode so growers make a critical decision whenever they decide on a partial fumigation or to not fumigate at all. The damage by nematodes is severe enough on almond that without methyl bromide or an effective alternative, the resulting orchards will be weaker with fewer roots and any damage with above ground pests will be increased. Fumigation is common in replant situations in the San Joaquin Valley. Additionally, availability of an effective pre-plant material has greatly reduced the need for annual post-plant treatments.

1,3 Dichloropropene is the closest replacement for methyl bromide, but its use for this purpose in California was suspended from 1990 to 1996 and today there are serious acreage restrictions and a limitation of 350 lb. per acre associated with its use. Use data are not available at this time. Excessive volatilization has been the key shortcoming to its recent use and the tree fruit industry has been searching for improved methods of application to limit in-field volatilization without jeopardizing efficacy. Prior to 1990, the normal treatment rates for 1,3 Dichloropropene were up to 800 lb. per acre. Newer methods of killing roots plus the lowered rates of 1,3 Dichloropropene and the use of a water seal containing metam-sodium biocide will soon receive field evaluation as a methyl bromide alternative. It is premature to predict the results in commercial settings (3).

Metam-Sodium – Applied at individual tree sites pre-plant to <0.01% of the acreage at an average rate of 60 lb. a.i. per acre. This material is difficult to move deep enough into the soil to be of much use (3).

Fenamiphos – For non-bearing trees only. Applied to soil to 0.02% of the acreage at an average rate of 7.26 lb. a.i. per acre. Efficacy is variable. No California registration is expected for bearing trees.

Sodium Tetrathiocarbonate – This material releases carbon disulfide when in contact with soil. Several small-scale field trials have shown that flood applications of this material can reduce ring nematode populations on almonds, thereby reducing the incidence of bacterial canker (3).

2. Alternatives

There are a few alternatives currently being used in trials. Work with ozone as a soil fumigant is ongoing in prunes. Preliminary data indicate the product moves at nematicidal concentrations for 6-12 inches from the point of injection. Cost projections based on trials indicate ozone could be applied at a cost comparable to other nematicides. Metabilities produced by myrothecium fungus were recently registered as a nematicide under the brand name DiTera. Performance of this product is highly variable in small plots and there is much about this biologically derived product that is not understood. DiTera is now receiving commercial evaluation in plots in prunes in the Sacramento Valley.

First year treatments of oxamyl via drip or microsprinklers can give protection against root lesion nematode. No registrations are expected even though there are no residues from this use. This material would be very beneficial for first year almonds.

3. Cultural Control Practices

Management of nematodes starts before planting an almond orchard. Soil samples should be taken to identify the nematode species present to determine a course of action (6). Continued fallowing for at least 4 years or use of non-host crop rotation can significantly reduce nematode populations before planting. However, this is not an economically feasible option (3).
To prevent the introduction of nematodes in an orchard, certified nematode free planting stock is used. Rootstock selection is also important because rootstocks for almonds differ in response to various parasitic nematodes. None of the more commonly used rootstocks are resistant to all the plant-parasitic nematodes. However Nemaguard peach, the most common almond rootstock, is resistant to all the common root knot nematode species found in California. The plum rootstock Marianna 2624 is also resistant to root knot nematodes but has limited utility because of soil and incompatibility problems (3).

4. Biological Controls

There are no known biological agents that are deliverable to soil or the surfaces of roots that will provide relief from nematodes (3).

5. Other issues

The anticipated loss of methyl bromide has prompted the tree fruit industry in California to search for other methods that result in death of the remnant roots. By cutting off trees at their trunks and painting the cambium region with glyphosate systemic herbicide, it has been possible to completely kill the roots so that 18 months later trees can be replanted without experiencing replant problem. (3). This work has only been done on young trees and gives only one year of relief. It is hoped that this work, combined with other nematode control strategies may replace some of the need for soil fumigation as well as the use of methyl bromide.

Vertebrate Pests (6)

Ground Squirrels, *Spermophilus beecheyi*

California ground squirrels are medium-sized rodents up to 20 inches long measured from the head to the tip of the tail. Ground squirrels are responsible for significant damage in almond orchards throughout the state. California ground squirrels live in underground burrows where they form colonies of 2 to 20 or more animals. They adapt well to human activities and are found along road or ditch banks, fence rows and within or bordering many agricultural crops. They are primarily herbivorous. During early

spring they consume a variety of green grasses and other herbaceous plants. When these begin to dry and form seeds, the squirrels switch to seeds, grains, and nuts.
Ground squirrels often infest almond orchards. They easily climb trees and feed on nuts from set to maturity and through harvest. Adult squirrels often cache seeds and nuts in their burrows, especially in the late summer and early fall. During this period almond losses greatly exceed the number the squirrels have actually consumed.
Squirrels dig extensive burrow systems, bringing soil and rocks to the surface creating mounds, which may cause damage to orchard equipment. The burrows and mounds create problems for harvesting operations, as nuts are shaken off the tree and swept off the ground.

1. Chemical Controls

Fumigation with gas cartridges can be effective in spring and early summer when soil moisture is high enough to retain the concentrations of toxic gases. It is ineffective in summer, particularly when the adult squirrels are estivating (summer hibernation) because the adult squirrels create a soil plug to seal themselves in the nest chamber.

Strychnine – 0.5% baits. Must be used in bait boxes. Strychnine is highly toxic to non-target mammals and birds.

Brodifacoum – 0.01% baits. No use data available as this is a fairly new use. A single feeding of this anticoagulant will kill squirrels.

Chlorophacinone – 0.005% and 0.01% baits used. Requires multiple feedings for 6 days or more. Used in bait boxes, or rarely broadcast (if label allows).

Diphacinone – 0.005% and 0.01% baits used. Requires multiple feedings for 6 days or more. Used in bait boxes, or rarely broadcast (if label allows).

2. Alternatives

Trapping is time-consuming, except with small populations.

3. Cultural Control Practices

Habitat modification by removing piles of orchard prunings and other harborage offers little relief, although this does make monitoring of squirrel activities easier.

4. Biological controls

Raptors have been found effective predators for squirrels, gophers and voles. Recent studies have found that owls can consume large numbers of these pests. Putting nesting boxes in the orchard can increase the predator activity.

5. Other issues

Rodent pests eat roots, nuts, or bark and can kill young trees outright. Rodent burrows and mounds interfere with orchard maintenance and harvesting operations and inflict structural damage on drip irrigation lines. It is important to establish a vertebrate pest control program that includes the following: correctly identify the species, alter the habitat to make the area less favorable for the pests, take early action and use a control method appropriate for the orchard and time of year, with due consideration for the environment. Finally, establish a monitoring system to know when controls are needed. (6).

Pocket Gophers, *Thomomys spp.*

Pocket gophers are stout-bodied, short-legged rodents 6 to 8 inches long. Pocket gophers are common in areas of abundant plant growth. They feed primarily on succulent underground parts of herbaceous plants. They live almost entirely underground. They create extensive burrows for living and feeding.
Pocket gophers frequently live in orchards. They are active throughout the year. In ideal situations, their numbers may reach 30 to 40 gophers per acre. They cause tree damage or death by girdling roots or crowns at or below the soil level.

1. Chemical Controls

Strychnine – 0.5% bait. Placed in the burrow by use of mechanical burrow builder or with hand probes. Usually very effective with virtually no secondary wildlife hazards.

Chlorphacinone and **Diphacinone** – 0.005% and 0.01% baits. Applied to burrows in the same manner as strychnine.

Aluminum phosphide – The only fumigant that has shown some degree of effectiveness. Time consuming to hand treat burrows with pellets and seal hole. Requires repeat treatments for effective control.

2. Alternatives

Modify habitat to remove vegetation and discourage gophers.
Chemical or mechanical repellents are not effective in controlling pocket gophers.
Traps can be placed in burrows with good results if the populations are small. Trapping is time consuming and expensive.

3. Cultural Control Practices

Habitat modification by removing piles of orchard prunings and other harborage offers little relief, although this does make monitoring of squirrel activities easier.

4. Biological controls

Bats and owls have been found effective predators for squirrels, gophers and voles. Recent studies have found that owls can consume large numbers of these pests. Putting nesting boxes in the orchard can increase the predator activity.

5. Other issues

Rodent pests eat roots, nuts, or bark and can kill young trees outright. Rodent burrows and mounds interfere with orchard maintenance and harvesting operations and inflict structural damage on drip irrigation lines. It is important to establish a vertebrate pest control program that includes the following: correctly identify the species, alter the habitat to make the area less favorable for the pests, take early action and use a control method appropriate for the orchard and time of year, with due consideration for the environment. Finally, establish a monitoring system to know when controls are needed. (6).

Post Harvest

Dried almonds are fumigated after harvest with phosphine gas primarily for control of navel orangeworm, peach twig borer, ants and storage pests. Navel orangeworm damage is directly linked to the presence of aflatoxins in almonds. Control of these insects is critical to maintain markets that demand insect-free almonds. Many countries require fumigation prior to export to control pests that could be present and to prevent infestations in route. The major alternative to phosphine is methyl bromide. All incoming almonds are fumigated with phosphine at label rates by the processor when they are received and usually again prior to shipping.

U.S.D.A.-ARS scientists at Fresno are currently investigating controlled atmosphere technology and the use of several possible candidate compounds (carbonyl sulfide, sulfuryl fluoride, and methyl iodide) as replacements for at least some of the current methyl bromide uses. These tests have just begun so it is too early to judge their potential usefulness for almonds. None of the chemicals under test are registered for use. The use of controlled atmosphere is very slow (e.g., 5 to 7 days or more) and would be extremely difficult to accomplish with large volumes of almonds and existing storage facilities.

Current Research

The anticipated loss of methyl bromide has prompted the tree fruit industry in California to search for other methods that result in death of the remnant roots. By cutting off trees at their trunks and painting the cambium region with glyphosate systemic herbicide, it has been possible to completely kill the roots so that 18 months after such a treatment trees can be replanted without experiencing the replant problem (3). At this point in time, none of this work has been conducted on trees older than 15 years and it only provides 1 year of nematode relief, but in concert with other nematode controlling strategies, this methodology may replace some of the need for soil fumigation.

Work with ozone as a soil fumigant is also ongoing on prunes. Preliminary data indicate the product moves at nematicidal concentrations for 6-12 inches from the point of

injection. Cost projections based on trials indicate ozone could be applied at a cost comparable to other nematicides.
For nematode control, metabolites produced by myrothecium fungus were recently registered as a nematicide under the brand name DiTera. Performance of this product is highly variable in small plots and there is much about this biologically derived product that is not understood. DiTera is now receiving commercial evaluation in plots in prunes in the Sacramento Valley.
First year treatments of oxamyl via drip or microsprinklers can give protection against root lesion nematode. No registrations are expected even though there are no residues from this use. This material would be very beneficial for the first year of starting almonds.

I. Challenges to Implementing Change

The challenges facing a reduced pesticide risk program are two-fold.

The first challenge is the regulatory threat of the Food Quality Protection Act (FQPA). This law, passed by Congress and being enforced by the Environmental Protection Agency (EPA), is the impetus which is now motivating many farmers to take a more in-depth look at what pesticide alternatives may be available. It has the possibility of taking away the chemical tools that many growers now consider indispensable.

The second and equally important challenge facing farmers is preventing pesticide residues from running off and entering into local watersheds. The push for clean water comes from many different sources, but has become an issue of increasing concern. Farmers have been targeted for their role in water pollution due to dormant spray run-off. It is apparent there is an immediate need for much more research and information in this area.

Other challenges include increasing pesticide resistance is occurring in most all crops and in all types of chemicals. Particularly vulnerable are the OPs and pyrethroids.

Further, worker safety issues present challenges. More stringent worker safety regulations with regard to pesticide use are now in place. Farmers must be aware of possible health risks and educate their workers on using Best Management Practices, substituting less toxic chemicals or biological control when possible and using caution when handling chemicals.

The second part of the challenge lies in actually implementing practices and strategies that reduce the risk of pesticides on the farm. Probably the single most important element in making the change is grower education. The challenge is in informing and demonstrating to growers that reduced risk systems can work for them without a sacrifice in quality or yield.

The greatest fear of growers seems to be that the practices will not be effective and will cause an economic hardship. Some reduced risk practices have not been scientifically validated, causing concerns about their effectiveness. The challenge is that growers must be open to new methods and be willing to make changes, not just in the way they treat their orchards, but in the way they think. Reduced risk programs will require rethinking and learning new tools. The reduced risk program is more difficult to administer than a conventional one. It may require more careful monitoring, making informed choices and accepting more risk.

Other challenges play a role as well. The majority of almond production (70%) is exported to nearly 100 different nations. Many of these countries require a chemical management system.

The challenges are many, but with projects like the Almond Pest Management Alliance, these challenges are being met head-on. Bringing together the many facets of almond production and those involved in educating growers is a great first step. This kind of an alliance makes a reduced risk future look possible.

J. Innovation

The most promising innovation in the almond industry is the Pest Management Alliance itself. The PMA is helping growers look at their orchards as a complete system, helping them to see the interrelationships and find a balance. The goal is to be able to control major almond pests with reduced risk systems, utilizing careful orchard monitoring, insect trapping to determine presence or absence, pheromones for mating disruption, biological control, beneficial insect releases, and cultural controls. Utilizing proper monitoring techniques and treating only when necessary will decrease the pesticide load in orchards, leading to decreased pesticide runoff.

These reduced risk systems reduce worker exposure and reduce health risks by reducing the total pesticide load present in the environment.

The following technical innovations for a reduced risk pesticide system only await wider promotion and adoption for industry-wide success.

- **Use of springtime Bt spray for control of PTB**-- the once common practice of a dormant OP spray for PTB control could be nearly eliminated.
- **Use of dormant oil for SJS and mite control--** the once common practice of a dormant oil and OP spray for SJS and mite control could in some cases be eliminated.
- **Hullsplit spray of Bt for NOW control--** Bt at hullsplit provides good control of NOW at low to moderate levels of NOW. OP use at hullsplit can be reserved for only major NOW outbreaks under rare conditions.
- **Cover crops and planted berm strips to reduce runoff--** Ground cover has been show to significantly reduce runoff thereby reducing pesticide load in rivers during the wintertime.
- **Winter sanitation for NOW control--** Although well known for many years, winter sanitation is not universally used in all areas. Winter sanitation, combined with an early harvest, can reduce the need for in-season pesticide sprays for NOW control.

• **Spinosad**-- Spinosad is very safe for humans and is a good reduced risk alternative for many pests. However, further testing is necessary in almonds to determine its effects on naturally occurring biological control.

The real innovation comes through education and encouragement of these reduced risk practices to growers throughout the state. Increased education about biological and cultural means of control is the key to reduced risks systems. Partnerships such as the almond PMA allow an effective means for teaching reduced risk practices through field days and demonstration projects. This grassroots approach has been shown to be very effective in educating almond growers about the challenges they face in producing an economical crop in an environmentally responsible manner.

K. Pesticide Use and Trends in California Almonds

On August 3, 1996, the Food Quality Protection Act (FQPA) was signed into law. The Environmental Protection Agency (EPA) must meet the following time table for pesticide review: 33% of applicable tolerance and exemptions must be reviewed by August 1999, 66% by August 2002, and 100% by August 2006. The following tables and graphs track the acreage of commercial almond plantings and the pesticide use.

In reassessing tolerances, FQPA requires that EPA consider, among other thing, the best available data and information on the following (Taken directly from EPA: Raw and processed Food Schedule for Pesticide Tolerance Reassessment):

- The aggregate exposure to the pesticide (includes exposure from residential pesticide uses and drinking water.
- The cumulative effects from other pesticides sharing a common mechanism of toxicity.
- Whether there is an increased susceptibility from exposure to the pesticide to infants and children.
- Whether the pesticide produces an effect in humans similar to an effect produced by naturally occurring estrogen, or other endocrine effects.

California commercial almond acreage has been increasing annually since 1990. Table 1 and Figure 1 shows this trend.

Table 1: California Commercial Almond Acreage.

Year	Total Almond Acreage (bearing and non-bearing)
1990 -1991	443,400
1991 - 1992	438,000
1992 - 1993	434,600
1993 - 1994	435,400
1994 - 1995	455,500

1995 - 1996	483,700
1996 - 1997	500,400
1997 - 1998	505,000
1998 - 1999	573,000

The increase in almond acreage statewide has also increased the amount of pounds of all pesticides applied. Table 2 shows this trend.

Table 2: Pesticide Use for Almonds 1993-1998

Year	**Pounds of All Pesticides Applied to Almonds**	**Number of Applications of All Pesticides Applied to Almonds**	**Pounds of Pesticide/Application of All Pesticides**	**Pounds of Pesticide/Total Acres**
1993	14,721,974.8268	143,235	102.78	33.87
1994	14,371,064.0702	147,700	97.30	33.00
1995	12,004,851.3276	154,125	77.89	26.36
1996	14,131,646.20	156,861	90.09	29.22
1997	14,467,690.42	109,689	131.90	28.91
1998	16,142,012.43	125,067	129.07	31.96

Pesticide Use

Organophospate Use

After showing a steady decline in use per acre from 1990-1995, organophosphate use showed a slight trend upwards in 1996 and 1997, only to decrease in 1998. However, despite the slight increase in use per acre in 1996 and 1997, organophosphate use per acre was approximately 1.5 pounds per acre throughout California. The 1.5 pounds of organophosphate applied per acre is down from the 2.0 pounds per acre applied in 1990. Figure 2 shows the trend of organophosphate use in California.

Carbamate Use

In 1990, less than 0.02 pounds of carbamates were applied to California commercial almonds. In 1997, approximate 0.05 pounds of carbamates was applied to commercial almond orchards throughout the state. The number of pounds applied dropped in 1998 to less than 0.04 pounds applied statewide. Figure 3 shows the trend of carbamates applied to commercial almonds in California.

Pyrethroid Use

Similar to carbamate use, pyrethroid use is also seeing an increase in pounds applied per acre statewide. With a switch away from organophospate use, more growers may be applying pyrethroids that accounts for the dramatic upswing in use. Growers may also be alternating between organophospate sprays and pyrethroid sprays which explains the peaks in use. Figure 4 documents pyrethorid use in California commercial almonds.

Bacillus thurigiensis (Bt) Use

Bacillus thurigiensis (Bt) has experienced a significant and dramatic increase in use since 1990. In 1990, the use of Bt was practically non-existent, however, in 1993 the use of Bt began to increase. By 1995, the peak use year, over 0.045 pounds per acre were being applied statewide. Despite the dip in Bt use, the amount being applied per acre statewide is over 0.03 pounds per acre.

Miticides

Miticide use in commercial almond orchards were classified by type of miticide used and not by how many pounds of miticide applied from1993-1998. Miticides used were Clofentizine (Apollo), Fenbutatin-oxide (Vendex), Propargite (Omite), and in 1993 only, Dicofol was applied on a very small amount of acres and does not show in the graph provided. The trend shows a small increase in the use of Clofentezine and a small increase in the use of Fenbutatin-oxide, but Propargite is the miticide used most. Figure 6 shows the various classes of miticides.

Fungicides
Fungicides help protect from harmful diseases which may have harmful effects against commercial almonds. Fungicides are listed according to which FQPA group they are listed in. There are three groups: Group 1, reviewed in 1999, Group 2, to be reviewed in 2002, and Group 3, to be reviewed in 2006. Table 3 shows the fungicides categorized according to FQPA group.

Table3: Fungicides according to FQPA review.

Group 1 1996	**Group 2 2002**	**Group 3 2006**
Benomyl	Fosetyl-Al	Copper
Captan	Metalaxyl	Copper Hydroxide
Chlorothalonil		Copper Sulfate
Iprodione		
Mancozeb		
Maneb		
Mycobutanil		

Most of the use of fungicides belong to Group 1 or to Group 3. Group 2 equates to a very small percentage of total fungicide use. Figure 7 shows fungicide use according to FQPA grouping.

Herbicides
Herbicide use in commercial almond orchards is important to guard against harmful weeds. The herbicides are also reviewed according to a time table. However, there are no herbicides listed in Group 4, which is to be reviewed in 2006. Table 3 lists the herbicides to be reviewed by group.

Table 4: Herbicides Group according to FQPA review.

Group 1 1996	**Group 2 2002**
2,4 D	Clethodim
EPTC	Dicamba
Oryzalin	Fluazifop-butyl
Oxyfluorfen	Glyphosate
Paraquat Dichloride	Napropamide
Pendimethalin	Norflurazon
Simizine	Sethozydim
Trifluralin	

Herbicide useage remains relatively constant with useage between the two groups even. Statewide, a total of approximately 2.5 pounds of herbicide, is applied per acre. There are currently no herbicides to be reviewed as part of Group 3 in 2006. Figure 8 shows herbicide useage.

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Figure 5: Bt useage per Total Almond Acres
1990-1998

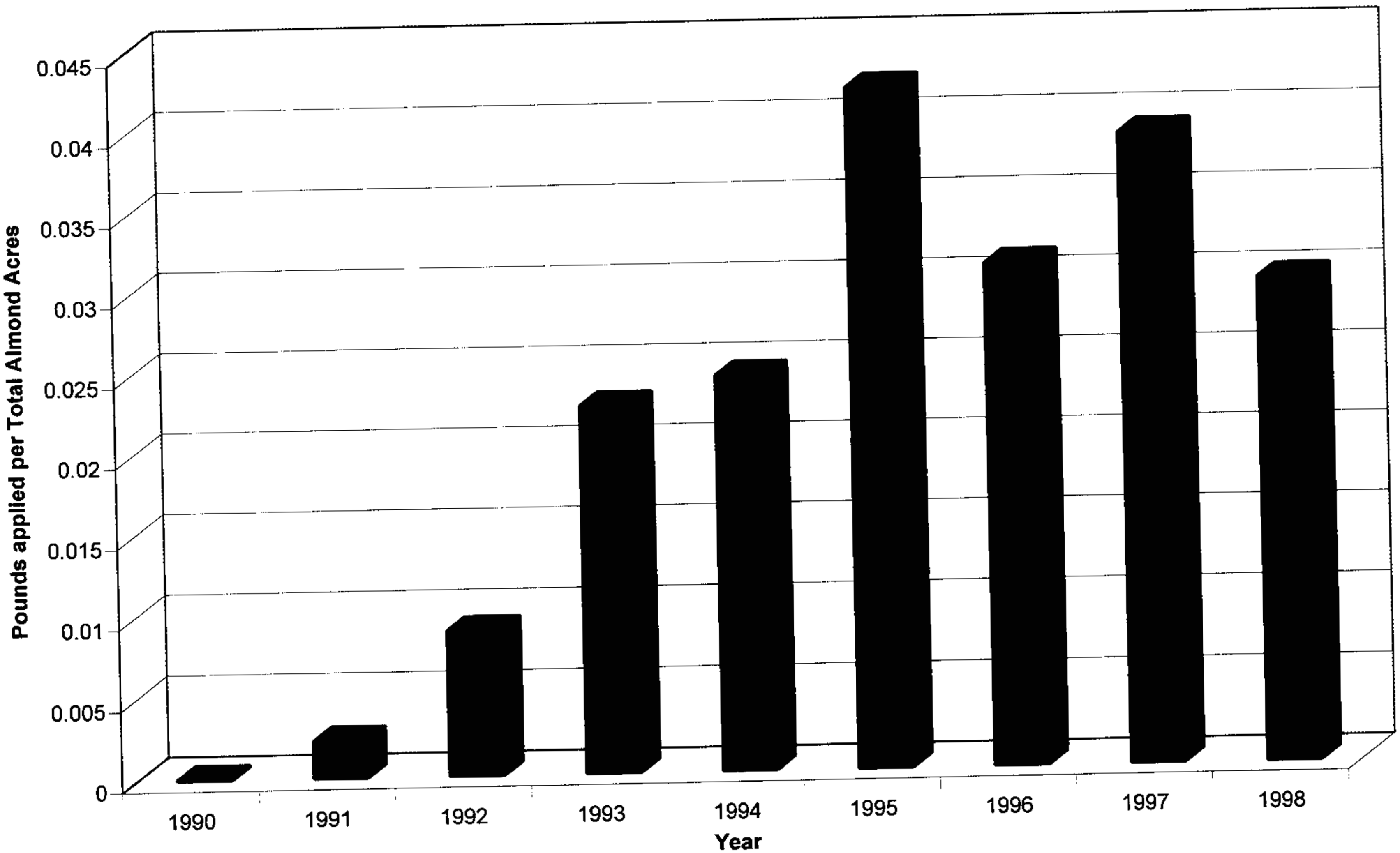

Figure 6: Miticide Use in California Almonds by Class 1990-1998

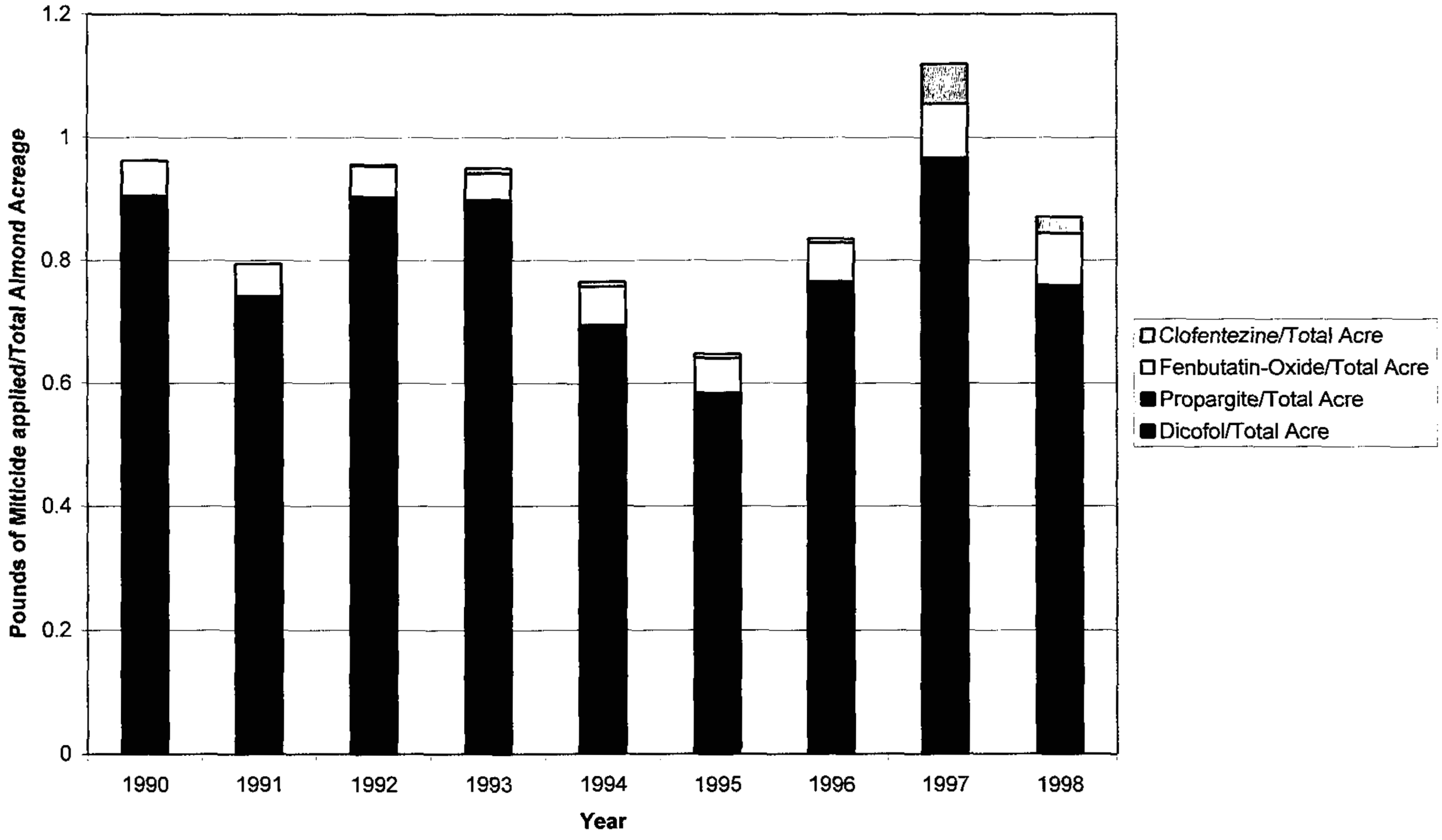

Figure 7: Fungicide Use by FQPA Group 1990-1998

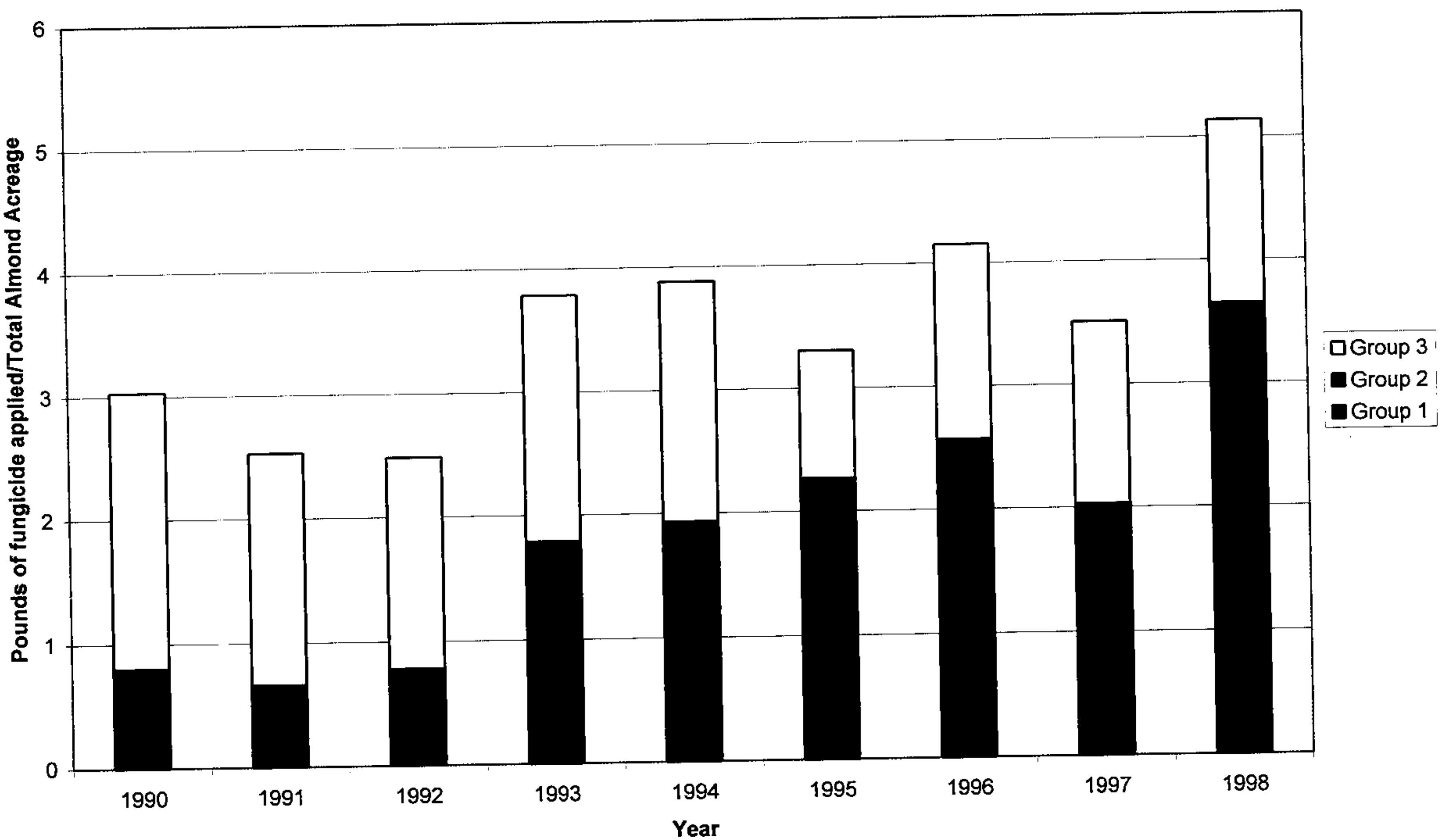

Figure 8: Herbicide Use by FQPA Group 1990-1998